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(56) Documents cited GB 1134556 GB 0980451 US 4130019 GB 1603061
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(71) Applicants Smiths Industries plc., 765 Finchley Road, London NW11 8DS.
(72) Inventors Kenneth Gordon McAinsh
(74) Agents Smiths Industries plc., J.N. Flint & P.L. Williamson, Cricklewood Works, London MW2 6JN.

(54) Measuring temperature electrically

(57) A thermocouple probe (1) suitable for use in aircraft gas turbine engines, has a tubular outer housing containing thermocouple junctions. One junction at the forward end of the probe is formed from conductors resistant to high temperatures, such as platinum and platinum-rhodium. At the rear, cooler, end of the probe, the conductors are joined to other conductors of a base metal. A further thermocouple junction (for deriving temperature compensation is located at the rear end in an isothermal plug is formed from conductors resistant only to lower temperatures. The conductors from each probe are connected to respective copper wires at an isothermal connector block (4) including a further temperature sensor. A computer 6 calculates the temperature at the hot end of the probe and provides signals to a warning and indication panel 7 and to utility devices 8, 9. Indications are given of the average instantaneous temperature and of maximum, minimum temperatures reached. An excessive temperature alarm is also provided.

Fig.1.

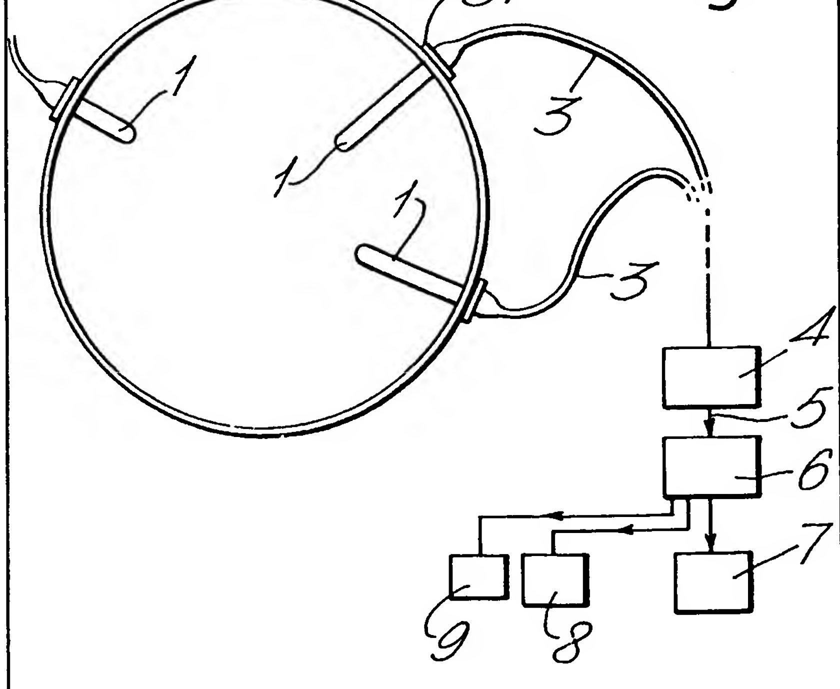

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Fig.1.

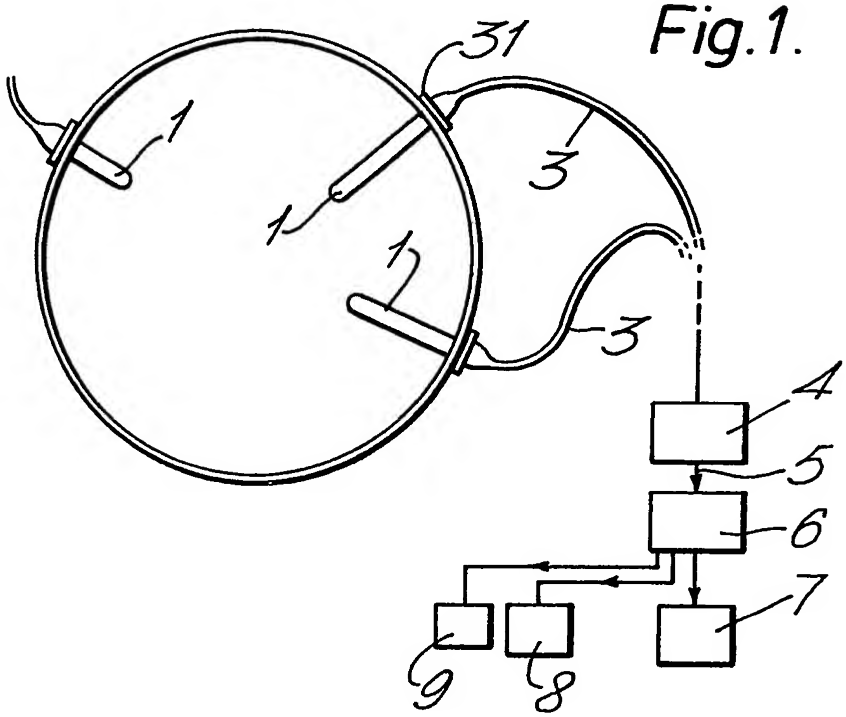
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Fig.2.

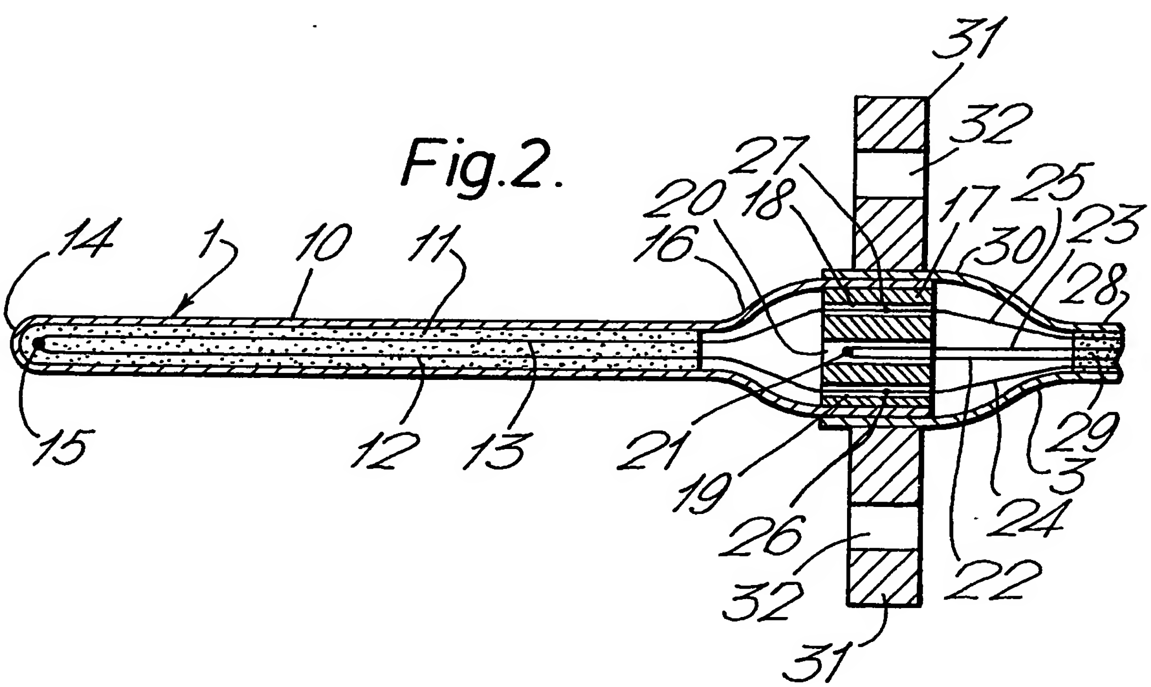
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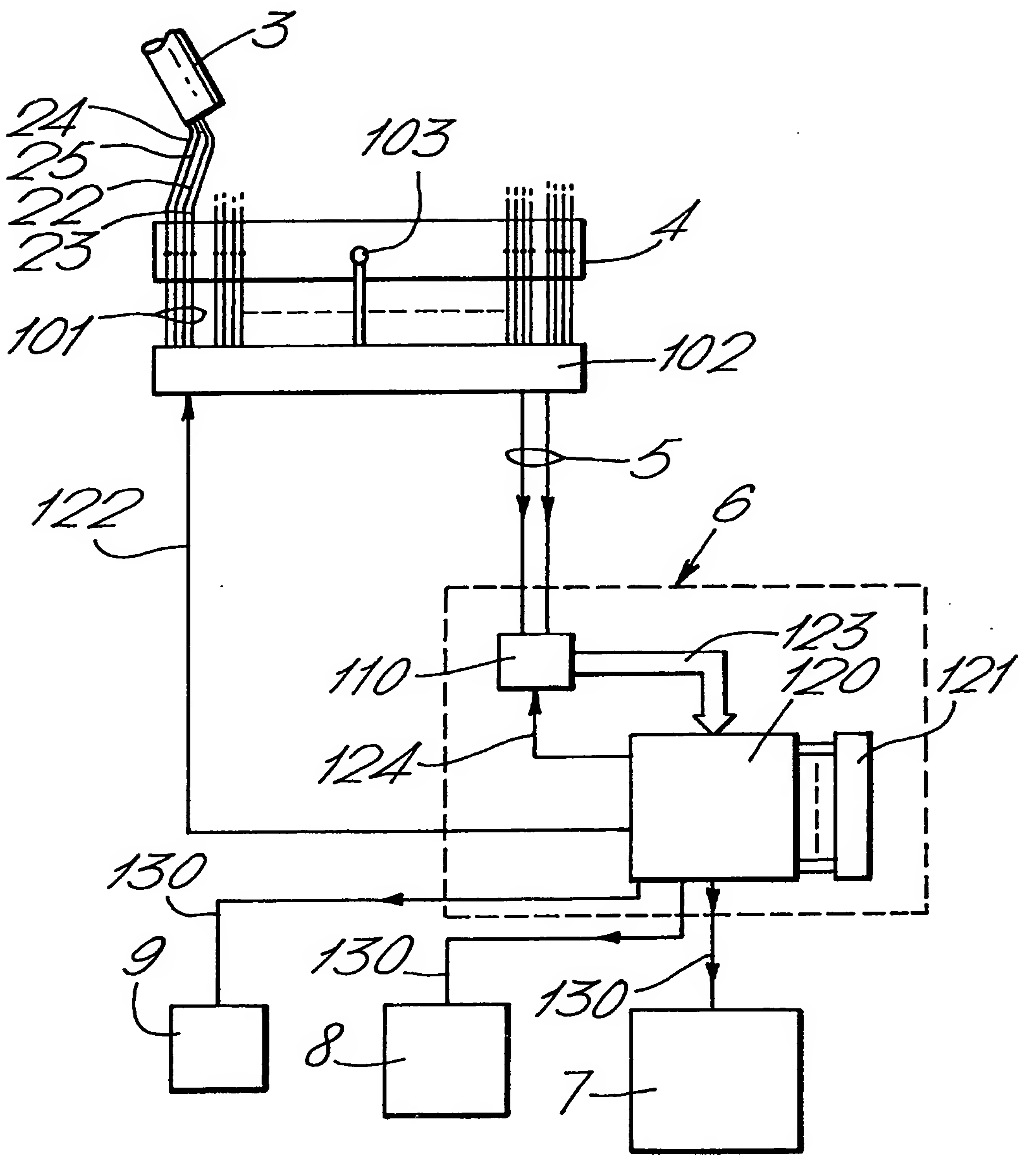
Fig.3.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SPECIFICATION

Temp rtur sensing

This invention relates to temperature sensing, and more particularly, to sensing high temperature such as, for example, are experienced in gas-turbine engines.

It is desired in gas-turbine engines to know the temperature in the turbine entry regions of the engine. Because, however, of the high temperatures in this region it is possible to measure such temperatures directly with thermocouples only by using noble metal junctions, such as of platinum and platinum-rhodium. The high cost of these metals prohibits their use and, instead, it is usual to employ other thermocouples located in a cooler region (such as, in the exhaust duct, jet pipe or low pressure nozzle guide vane plane) and to compute the temperature in the region of interest from the thermodynamics of the engine. This obviously has disadvantages since the thermocouples will not respond so rapidly to temperature change in the region of interest. Also, damage or deterioration in the combustion or turbine entry region may not be readily apparent from the temperature in the region where the thermocouples are located. Additionally, errors that are inherent in the computation mean that larger margins for error must be allowed, thereby preventing the engine being operated close to its limits, where it would be more efficient.

In present gas-turbine engine thermocouple probe arrangements several thermocouples are used, these being connected together to give an output that is indicative of the average temperature in the region of interest. Whilst this is satisfactory in most cases, it does have the disadvantage of being unable to signal localised temperature changes which might be important in indicating an engine defect. Failure of an individual thermocouple, by its conductors shorting together at a region remote from the true junction, would provide an additional spurious junction at a different temperture, thereby altering the average temperature output.

It is an object of the present invention to provide a temperature sensing assembly that can be used to overcome the above-mentioned disadvantages.

According to one aspect of the present invention there is provided a thermocouple probe assembly including: a first high-temperature resistant thermocouple junction located at a first region of said probe for exposure to high temperature, the individual conductors of said first junction being connected to lower-temperature resistant conductors at a second region of said probe which is exposed to lower temperatures; and a second lower-temperature resistant thermocouple junction located at said second region of said probe, said second thermocouple junction providing an output for use in compensating the output of said first thermocouple junction.

In this way, any noble metal conductors may b of short length, thereby enabling a high temperature probe assembly to be produced at relatively low cost.

The conductors forming the first junction may be of platinum and platinum-rhodium respectively, while the c nductors f rming th s cond juncti n may be f a nick l-aluminium alloy and a nickel-chromium alloy respectively.

The assembly may include an outer tubular housing, said first junction being located towards one end of said housing. The housing may have a support member at said other end, said conductors of said first junction being connected at said support member, and said second thermocouple junction being supported by said support member. The support member may be of an electrically-insulative and thermally-conductive material such as beryllia.

According to another aspect of the present invention there is provided a probe arrangement including a probe assembly as specified above and computer means, said computer means receiving the outputs from said first and second thermocouple junctions and being arranged to derive an indication of the temperture of said first region from the outputs of said first and second thermocouple junctions.

A thermocouple probe assembly and arrangement for a gas-turbine engine will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of the probe arrangement;

Figure 2 is a cut-away view of an individual probe assembly to a greater scale than in Figure 1; and

Figure 3 shows a part of the arrangement in greater detail.

With reference to Figure 1, the thermocouple arrangement comprises twelve probes 1 (only three of which are shown) which are mounted around the outer casing 2 of a gas-turbine engine in the turbine entry regions. The probes 1 project radially inwards through the casing 2 into the gas stream through the engine. The output cables 3 from the probes 1 extend to an isothermal connection block 4 mounted on the engine at a cooler location, cables 5 from the connection unit extending to a computing unit 6. The computing unit 6 provides signals to a warning and indication panel 7 and to other utilising devices 8 and 9.

The probes 1, shown in greater detail in Figure 2, are of a conventional external configuration, having an outer tubular housing 10 of a heat-resistant material, such as platinum, which contains a mineral filling 11, such as of magnesium oxide. Two wires 12 and 13, respectively of platinum and a platinum-rhodium alloy, extend along the probe 1 being electrically-insulated from one another by the mineral filling 11. At the tip 14 of the probe 1 the two wires 12 and 13 are joined together forming a first thermocouple junction 15. At the rear end 16 of the probe 1 the housing 10 is flared to an increased diameter and is closed by a cylindrical plug 17 of an electrically-insulative but thermally-conductive material (such as beryllia). Any space between the mineral filling 11 and th isothermal plug 17 is filled with a suitable electrically-insulative material. The plug 17 has three passages 18, 19 and 20, two of which 18 and 19 receive the r ar ends of the wires 12 and 13, the third passage 20 containing a second thermocouple junction 21. The second thermocou-

ple junction 21 is formed by two wires 22 and 23 of a nickel-aluminium alloy (such as, Alumel) and a nickel-chromium alloy (such as, Chromel) respectively.

The rear ends of the wires 12 and 13 of the first junction 15 are joined to respective base metal extension leads 24 and 25 (such as, of nickel, stainless steel or copper) within the plug 17. These joins form additional junctions 26 and 27 which are maintained at the same temperature as the second junction 21 by the isothermal plug 17.

The extension leads 24 and 25, and the wires 22 and 23 of the second junction 21 extend rearwardly of the probe 1 within an outer housing 28 of stainless steel or Inconel 600 and constitute the output cable 3 of the probe. The cable 3 is insulated by a magnesium oxide filling 29, the forward end 30 of the cable housing 28 being flared to an increased diameter and sealed about the rear end 16 of the probe 1. Any space within the forward end 30 of the housing 28, between the plug 17 and the cable filling 29, is filled with a suitable electrically-insulative material.

A stainless steel flange 31 extends radially of the probe about the joint between the cable housing 28 and the probe housing 10. The flange 31 has bolt holes 32 that are used to secure the probe assembly with the engine casing 2.

With reference now to Figure 3, at the isothermal connection block 4 the leads 24 and 25 from the first thermocouple junction 15, and the wires 22 and 23 from the second junction 21 of each probe 1 are joined to respective copper wires 101. The four wires 101 in respect of each probe 1 are connected to respective inputs of a multiplexer 102 together with the output from a common temperature sensor 103 mounted on the block 4 for cold junction compensation.

The computing unit 6 is also mounted on the engine and may be cooled, for example, by the fuel supply to the engine. The computing unit 6 includes an analogue-to-digital converter 110, a microprocessor based control unit 120 and a store 121. The control unit 120 addresses the multiplexer 102 via lines 122 to connect the selected multiplexed output to the converter 110. The converter 110 in turn supplies signals to the control unit 120 via lines 123 in response to control signals on lines 124.

The computing unit 6 supplies output signals on lines 130 to the panel 7 and to a flight recorder unit 8 representative of the average engine temperture. The unit 6 also provides signals representative of localised change in temperature indicative of a fault in the engine. These signals, however, are not generally required by the pilot and are hence only supplied to the flight recorder 8 - they are also utilised when ground testing the aircraft.

In operation, the control unit 120 calculates the temperature at the tip 14 of each probe 1 by suitable software compensation of the outputs of both thermocouple junctions 15 and 21, and the temperature sensor 103 on the isothermal block 4. These temperature signals are supplied to the stor 121. The control unit 120 calculates th average instantaneous temperature and suppli s representative f this value to the panel 7. Signals representative of the highest and lowest temp ratures, or the temperature range are also supplied for display on the panel 7. If this range xceeds a predetermined limit, indicating the presence of a localised region of excess temperature an alarm is given. Alternatively, action could be taken automatically, such as, by shutting off supply of fuel to the engine and activating fire extinguishers. The output of the computing unit 6 is also used for engine control purposes and, in this respect, is shown as being supplied to the utilising device 8.

In addition to comparing the instantaneous outputs from the individual thermocouples, the change in output of each thermocouple is monitored by comparing its instantaneous output with the output from a previous sampling of the same thermocouple. Alternatively, or additionally, the average temperature may be stored for each sampling cycle and the change in average temperature monitored over a period of time by comparing the instantaneous average temperature with that from a previous sampling cycle. Engine life monitoring facilities may also be provided by integrating with respect to time the temperature, or excessive temperatures, recorded by the unit 6.

By forming the thermocouple junctions of noble metal conductors of only short length the cost of the thermocouple is kept at a minimum whilst permitting high temperatures to be measured directly. This enables the probes to be located within hotter regions than is possible with base metal junctions and thereby enables a more accurate indication of temperature within the hot region to be determined.

An advantage is also achieved by monitoring and comparing the individual outputs of the thermocouples since this enables localised temperature and temperature changes to be determined. Engine health may also be monitored by comparing the temperature distribution within the engine with a stored temperature distribution.

CLAIMS

1. A thermocouple probe assembly including: a first high-temperature resistant thermocouple junction located at a first region of said probe for exposure to high temperature, the individual conductors of said first junction being connected to lower-temperature resistant conductors at a second region of said probe which is exposed to lower temperatures; and a second lower-temperature resistant thermocouple junction located at said second region of said probe, said second thermocouple junction providing an output for use in compensating the output of said first thermocouple junction.

2. A thermocouple probe assembly according to Claim 1, wherein the conductors forming said first junction are of platinum and a platinum-rhodium alloy respectively.

3. A thermocouple assembly according to Claim 1 or 2, wherein the conductors forming said second juncti n are of a nickel-aluminium alloy and a nickel-chromium alloy r spectively.

4. A thermocouple probe assembly according to any one of the preceding claims, wherein said

ass mbly includes an outer tubular housing and wherein said first juncti n is located towards ne end of said housing and said second junction is locted towards the other end of said housing.

5. A thermocouple probe assembly according to Claim 4, wherein said tubular housing has a filling of an electrically-insulative mineral material.

6. A thermocouple probe assembly according to Claim 4 or 5, wherein said housing has a support member at said other end, wherein said conductors of said first junction are connected to said lower-temperture resistant conductors at said support member, and wherein said second thermocouple junction is supported by said support member.

7. A thermocouple probe assembly according to Claim 6, wherein said support member is of an electrically-insulative and thermally-conductive material.

8. A thermocouple probe assembly according to Claim 7, wherein said support member is of beryllia.

9. A thermocouple probe assembly substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

10. A thermocouple probe arrangement including a probe assembly according to any one of the preceding claims and computer means, said computer means receiving the outputs from said first and second thermocouple junctions and being arranged to derive an indication of the temperature of said first region from the outputs of said first and second thermocouple junctions.

11. A thermocouple probe arrangement according to Claim 10 including a plurality of assemblies according to any one of Claims 1 to 8.

12. A thermocouple probe arrangement according to Claim 11 including connector means at which said lower-temperture resistant conductors and conductors of said second junction are connected with wires of a base metal.

13. A thermocouple probe arrangement according to Claim 12, including temperature sensing means mounted with said connector means.

14. A thermocouple probe arrangement according to Claim 13, wherein said computer means receives the output from said temperature sensing means, and wherein said computer means is arranged to derive an indication of the temperature of said first region from the outputs of said first and second thermocouple junctions and said temperature sensing means.

15. A thermocouple probe arrangement according to any one of Claims 10 to 14, wherein said computer means is arranged to provide an alarm signal when the temperature comes outside a predetermined value.

16. A thermocouple probe arrangement substantially as hereinbefore described with reference to Figures 1 and 3 of the accompanying drawing.

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